DRAFT

SUMMARY REPORT

RELIABILITY OF SOLDERLESS WIRE-WRAP CONNECTIONS

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QUALITY PROCESSES
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WIRE WRAP
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I. SCOPE

This investigation surveys the reliability of solderless wrap connections as measured against established government and commercial standards. The information compiled here is a result of industry test and is in addition to information contained in the reliability report of 12-63.

II SUMMARY

The documents reviewed here indicate some disagreement on the reliability of solderless wire wrap.

Chrysler Corporation studies base their reservations on this process because of less resistance to vibration as opposed to solder connections. In addition, Chrysler claims no advantage for solderless wrap from a manufacturing standpoint since MIL-G-11990 requires stranded wire which cannot be wrapped until the wire is tinned.

Boeing studies, which were quite lengthy, did not indicate significant deterioration as a result of the vibration test and was generally favorable in other test areas.

General Electric Company's resume of their experience with wire wrap was one of excellent reliability as applied to television equipment. Another study by General Electric indicates no serious change in resistance of this connection under varying environmental conditions.

Bell Telephone Labs found solderless wrap mechanically stable and has less tendency to break due to vibration than solder connections.

The results here indicate that the wire wrap process is very reliable. The differences noted on the vibration test were due primarily to the method of wrapping and vibrating the terminal.

TEST RESULTS #1

III. Title: Wire Wrap Resume - F. B. Esposito, General Electric Company

Results obtained from wire wrap operations on the "K" chassis.

# of Chassis Produced	# of Wire Wraps	Avg. Stripping Force (lbs.)
172,998	2,421,972	11 lbs.
# of Defects Found at Line Inspection	**# of Defects Found at Final Inspection**	**# of Field Complaints on Wire Wrapped Joints**
9/196,000	0	0

Conclusion - In making an overall area check of Final Test, IF and RF Test, Quality Lab and Life Test, there were no instances of defects traceable to any of 2,421,972 wire wrap joints. A cost improvement was realized in using wire wrap.

III. TEST RESULTS #2

Title: "Twist Wrap Joint Test" - J. B. Shickel, General Electric Company

Test Conditions

1. Heat Cycles

-30°C. to 85°C. 30 minutes at each temperature with 30 seconds required to change temperature. 5 hours total time.

2. Humidity

90% relative humidity. 40°C. for 22 hours per day for a total of 500 hours.

3. Vibration

Test boards were not mounted to shake table, but were allowed to bounce on table in random motion. Amplitude of vibration was 1/2" at 1700 C.P.M. for one hour.

4. Salt Spray

Chamber operated at 97°F. at 2/3 saturation of salt mist for 54 hours.

A. Results of Resistance Change in ohms with Environment and Terminal Material for Solderless Wrap

Type Terminal	Resistance As Rec.'d	After 5 Heats	After Humd. 500 Hrs.	After 5 Heats & Vib. (1 Hr)	After Salt Sp. 54 Hrs.
Terneplated Steel	.00873	.0102	.01077	.01043	.0105
Brass	.0097	.0105	.0130	.0104	.0104
Zinc Plated Steel	.0114	.0119	.0122	.0125	.0132

B. Results of Resistance Change with Environment and Terminal Material for - Soldered Connections

Type Terminal	Resistance As Rec.'d	After 5 Heats	After Humd. 500 Hrs.	After 5 Heats & Vib. (1 Hr.)	After Salt Sp. 54 Hrs.
Terneplated Steel	.0088	.00609	.006	.0061	.00646
Brass	.00784	.00521	.0052	.00515	.00518
Zinc Plated Steel	.011	.0070	.00769	.00773	.00762

Conclusion - From the tabulation of resistance readings taken following each test, it may be seen that no significant change of resistance occurred in any of the circuits.

III. TEST RESULTS #3

Title: Feasibility Study of the Wrap-Around (Solderless) Electrical Connection
J. C. Huber, Chrysler Corporation

Test Conditions

1. Vibration

Sonntag fatigue testing machine model SF-2 was operated at 1800 C.P.M. with terminal held rigid and wire leads vibrated up and down. The time to failure was recorded. Wire deflection varied - (1/4"-3/8") to (3.8"- 1 1/32")

2. Temperature

Connections were heated to 300°F. for 1/2 hour then cooled -70°F. for 1 1/2 hours.

3. Salt Spray

Salt Spray conditions were as specified in MIL-STD-202A.

Stripping Force (lbs.)

Terminal Material	Solid AWG 22	After Temp. Cycle	Stranded Soldered Tinned AWG 22	After Temp. Cycle	Solid AWG 20	After Temp. Cycle	Stranded Soldered Tinned AWG 20	After Temp. Cycle
Aluminum	31.7	30.7	27.3	26.6	42.8	52.8	42.5	37.4
Phosphor Bronze	46.9	46.1	22.2	18.2	29.3	42.0	15.0	26.5
Nickel Silver	41.0	46.5	28.6	30.4	47.8	52.3	38.3	39.1
½ Hard Brass	28.1	26.1	18.5	23.2	35.3	32.6	27.1	32.1
Full Hard Brass	23.0	22.9	26.8	20.4	24.5	34.7	28.7	22.4

TEST RESULTS #3 (cont.)

VIBRATION FATIGUE

Type Connection	Wire Size	Time-Seconds	Cycles X1000
Solid Wrapped	24	169	5.2
Solder Tinned, Stranded, Wrapped	24	1,611	48.4
Stranded Soldered	24	4,177.7	126
Solid Wrapped	22	495.8	15.2
Solder Tinned, Stranded, Wrapped	22	640.8	19.2
Stranded Soldered	22	7,939	238
Solid Wrapped	20	1,861	56
Solder Tinned, Stranded, Wrapped	20	6,070.8	183
Stranded Soldered	20	7,792.4	235.8
Solid Wrapped	18	610.4	18.4
Stranded Soldered	13	24,832.5	598.6

Note: Report indicated the solid wire wrapped connections were not of the modified type with 1½ turns of insulation.

CONDUCTIVITY (RESISTANCE IN OHMS)

Type of Connection	Avg. As Fabricated	Avg. Increase Temp. Cycle And 194 Hrs. Salt Spray
Solid Wrapped AWG 24	.0115	.0005
Soldered Tinned Stranded Wrapped AWG 24	.0106	.0009
Soldered Stranded AWG 24	.0099	.0009
Solid Wrapped AWG 20	.0049	.0001
Soldered Tinned Stranded Wrapped AWG 20	.0048	.0001
Soldered Stranded AWG 20	.0043	.0000

III. TEST RESULTS #3 (cont.)

Resistance of Terminal Material Vs. Heating

Type Terminal	Resistance (ohms) As Wrapped	Resistance After 470°F. For 4 Hrs.
Aluminum	.0047	.0277
Full Hard Brass	.0046	.0051
Half Hard Brass	.0044	.0045
Nickel Silver	.00590	.0063
Phosphor Bronze	.0049	.0051

Conclusion of Testing Agency

The wrap-around solderless connection is not superior to the solder connection except in salt spray exposures longer than 168 hours and elevated temperature applications to 470°F.

Stranded wire cannot be wrapped unless it has been dip-tinned or solder-tinned.

Wrap around solderless connections will not withstand vibration fatigue as well as soldered connections.

III. TEST RESULTS #4

Title: "Feasibility Study of Wrapped Wire Connections with Chem Milled Terminals" - H. J. Studer, J. Newcomb, Boeing Company

Test Conditions

Accelerated Aging

Connections were exposed to 175°C. for three hours, then temperature was returned to room temperature and strip force and resistance was measured.

Thermal Cycling

Thermal test were performed as specified in MIL-STD-202B Method 102A.

Vibration Test

The vibration testing environment consisted of an approximately logarithmic sweep from 5 to 2000 to 5 cycles per second in 16 minutes at ±10G limited to 0.60 inches D.A. in each of three mutually perpendicular axes.

Shock

This test was performed in accordance with MIL-STD-202B Method 202A.

Hydrogen Sulfide Atmosphere

Test samples were exposed to a hydrogen sulfide atmosphere for a period of 48 hours.

Humidity

Test samples were subjected to 95% ±5% relative humidity for 96 hours, after prior aging, thermal cycling, vibration and shock, and H_2S atmosphere.

Salt Spray

Test samples were subjected to salt spray conditioning in accordance with Method 101A, MIL-STD-202B, for a period of 96 hours.

III. TEST RESULTS #4 (cont.)

Strip Force Vs. Number of Turns Per Wrap

Number of Turns	Strip Force (lbs.) Test Terminal	Chem-Milled Terminal
4	8.4	15
5	12.6	17.6
6	16	21
7	19	23
8	19.5	27
9	22	---

Strip Force Vs. Wire Elongation

Elongation	Strip Force (lbs.) Test Terminal	Chem-Milled Terminal
35%	16	19.6
12%	21.6	23.0

Millivolt Drop Vs. Environment (Chem-Milled Terminals)

Control	Voltage Drop (Mv) Standard Wrap	Modified Wrap
Control	.40	.18
After Ageing	.50	.16
After Vibration	.54	.14
After H_2S Atmos.	.80	.24
After Humidity	.60	.14

Millivolt Drop Vs. Environment (Test Terminals)

Control	Voltage Drop (Mv) Standard Wrap	Modified Wrap
Control	.3	.13
After Ageing	.33	.12
After Vibration	.34	.12
After H_2S Atmos.	.40	.16
After Humidity	.30	.11

Conclusions - It was found that chem-milled wrapped terminals equalled or exceeded the minimum criteria for wrapped wire connections. No visual or functional deterioration was observed as a result of vibration and shock test.

Little correlation was found between strip force and steady state contact resistance. Transitory contact resistance measurements seem to give a better indication of electrical stability.

III. TEST RESULTS #5

Title: Solderless Wrapped Connections

R. H. Van Horn
Bell Telephone Labs

Solderless Wrapped Connections

Humidity and Corrosion-Exposure Test

Terminal Material	No. of Wraps	Vibration Hours	0°F. Hours	180°F. Hours	Hours in Corrosive Agent	Months at 85°F. 90% Rel. Humd.	Connections with Resis. Above .002 ohms
Untinned Brass	6	50	2	2	½	21	None
Brass-Nickel Plated and Tinned	3	0	2	2	½	9	25
Brass-Nickel Plated and Tinned	4	0	2	2	½	10½	5
Brass-Nickel Plated and Tinned	5	0	2	2	½	10½	1
Brass-Nickel Plated and Tinned	6	0	2	2	½	10½	None
Brass-Nickel Plated and Tinned	6	50	2	2	½	2	None
Brass-Nickel Plated Un-Tinned	6	50	2	2	½	½	None
U-Formed Untinned Nickel Silver	6	50	2	2	14	30	None
Untinned Nickel Sil.	4	0	2	2	2/3	10	None
Steel-Tin Plated	4	0	2	2	½	6½	None

Conclusion - The test described indicates that solderless wrapped connections are practical when wrapping #24 solid tinned copper wire on flat punched terminals of brass or nickel silver where the width is one-sixteenth inch and the thickness varies from .010" up to one-sixteenth inch. These connections are mechanically stable, and have less tendency to break due to hendling and vibration than solder connections.

IV. CONCLUSIONS

Results of test shown here indicate this type connection is reliable within the environmental conditions stated. Although Chrysler test indicates solder connections to be more resistant to vibration than solderless wrap, Boeing, Bell Labs and General Electric test shows the wire wrap connection to be satisfactory.

The variations found in test results on vibration seem to be due to the method of wrapping used and also the type vibrator employed.

The Chrysler test did not indicate that the modified wrap was used. The modified wrap, which has $1\frac{1}{2}$ turns of insulated wire on the terminal, tends to absorb part of the vibration reducing the force transmitted to the portion of the wrap where the bare wire is in contact with the terminal. This factor probably accounted for part of the failure of wire wrap on vibration.

Another significant fact, in the Chrysler test on vibration, was that the terminals were held rigid while the vibrator moved the connecting wires in an up and down motion.

This type test seems to evaluate the strength of the wire rather than the type connections, and is contrary to other vibration test reviewed.

V. REFERENCES

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